Characteristics, Evolution and Mechanisms of the Asian Summer Monsoon Onset over the Southeast Asia

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ABSTRACT

Based on the 1979-1995 mean pentad reanalysis data, the climatological characteristics and physical mechanism of the Asian summer monsoon (ASM) onset are investigated. A special focus is whether the ASM onset first commences over the Indochina Peninsula and why the ASM is established earlier over Southeast Asia than over India. The thermal forcing of the landmass in the lower latitudes of Asian continent on the seasonal transition is also investigated.

Keywords: Asian summer monsoon, South China Sea, Indochina Peninsula, Rainfall

1. Introduction

The time for the onset of various components of the ASM has long been of great interests. According to the investigation of previous scientists, the ASM onset first commences over the South China Sea in early to mid May, which was considered to be the earliest in the tropical Asia. However, some recent studies also suggested that the earliest onset of the ASM may not necessarily commence over the SCS. Indeed, heavy rainfall begins climatologically over the Indochina Peninsula in early May, about 10-15 days earlier than the SCS (Lau and Yang 1997; Matsumoto 1997; Webster et al. 1998; Wu and Zhang 1998; Wu and Wang 2000). However, the occurrence of heavy rainfall during the seasonal transition period does not necessarily represent the ASM onset. Simply using rainfall and/or outgoing longwave radiation (OLR) to argue for the ASM onset first occurring over the Indochina Peninsula may therefore not be sufficient. In fact, the ASM onset is quite a complicated process that includes not only an abrupt increase in rainfall, but also a seasonal reversal of the large-scale ocean-land thermal contrast and the associated reversal of atmospheric circulation. Therefore, it seems reasonable to re-examine the ASM onset date from the physical mechanism perspective, i.e. by examining the dynamic and thermodynamic variations in the planetary circulation rather than only the rainfall or convection. Here the NCEP/NCAR reanalysis data is employed to investigate the climatological characteristics and physical mechanism of the Asian summer monsoon (ASM) onset.

2. Result

An examination of thermodynamic and dynamic quantities confirms the previous result that the ASM onset

commences first over the Indochina Peninsula. The characteristics not only include the earliest active convection and rainfall, but also the earliest reversal of meridional gradient of temperature throughout the entire troposphere and the corresponding establishment of an easterly vertical wind shear (Fig.1). The convergence of southwesterly flow from the Bay of Bengal (BOB) vortex and easterly winds associated with the subtropical anticyclone over the South China Sea (SCS) accounts for the first characteristic. The last two features are responsible of the upper-level warming due to the vertical transport of latent heat through cumulus- and turbulence-induced eddies in convection.

A new criterion for the tropical ASM onset is proposed by considering both the rainfall and the reversal of the part of planetary-scale circulation, and then the advance of ASM in the tropical region is obtained (Fig.2). It appears that the ASM onset occurs first over the southwestern Indochina Peninsula in early May, and then advances to the north on May 16-20. Over the SCS, the onset starts in the fourth pentad of May and the monsoon covers the entire region by the end of May. A similar onset process is found to commence over the eastern Arabian Sea, India and western BOB in the last pentad of May, and the complete establishment of ASM over India is accomplished in mid June. In the process of the onset of each component of the ASM, the overturning of upper-level planetary-scale circulation strongly depends on the reversal of the meridional temperature gradient. Over the Indochina Peninsula, the seasonal transition of upper-level temperature results from convection–induced diabatic heating, while over western Asia it is attributed to the subsidence warming induced by the active ascending motion over the former region.

The steady increase in surface sensible heating over the Indian subcontinent and the latent heating over the tropical Indian Ocean in April to early May appear to be the major impetus for the development of the cyclonic vortex over the BOB. A similar enhancement over the Arabian Peninsula and the surrounding regions is also identified to be crucial to the development of the cyclone over the Arabian Sea, and then ultimately to the ASM onset over India. Due to its later seasonal transition versus the tropical region, the thermal forcing of the Tibetan Plateau appears to have little influence on the ASM onset over the Indochina Peninsula in early May.

Reference

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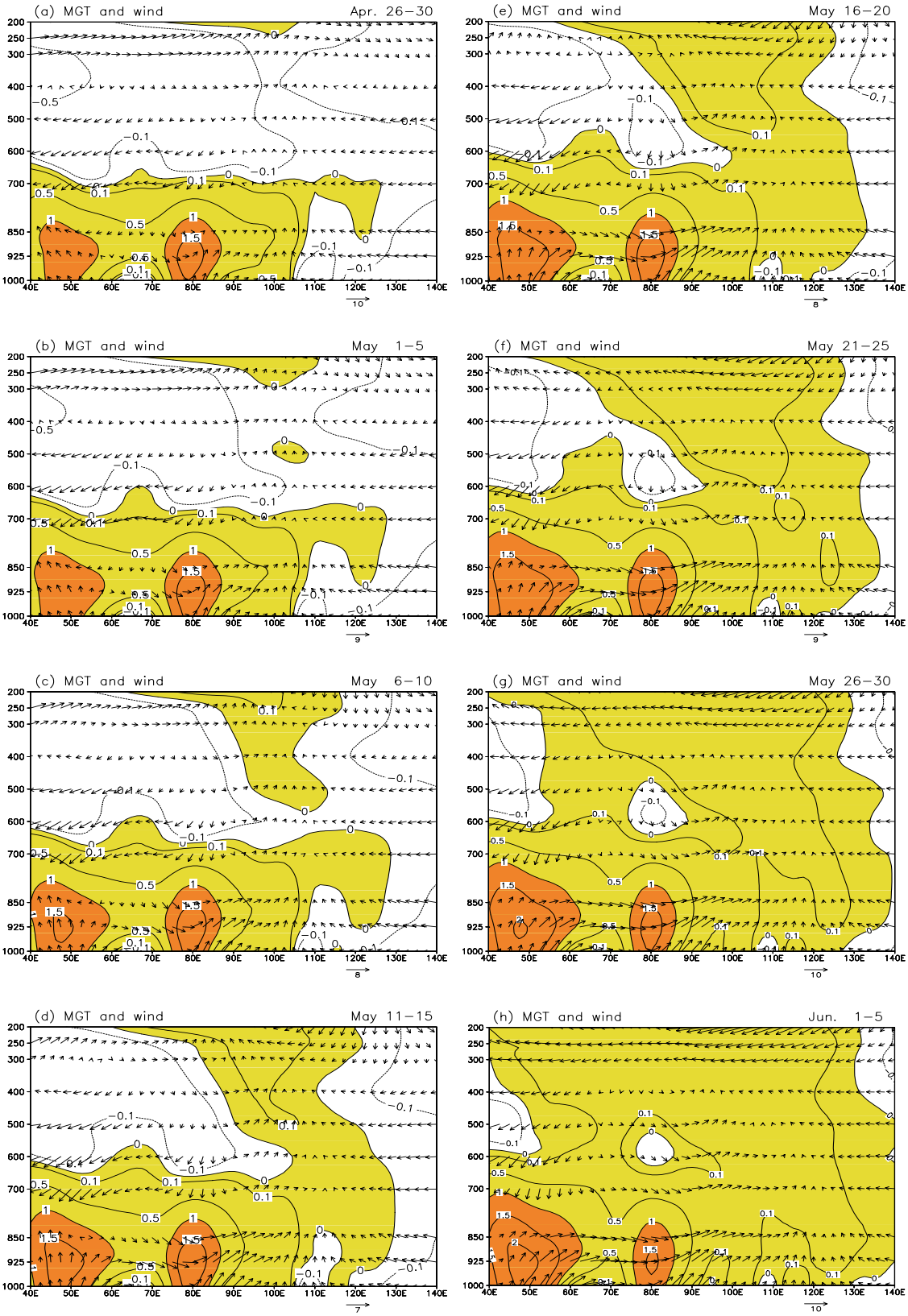

Fig. 1. Longitude-pressure cross-sections of pentad mean meridional gradient of temperature (MGT, contours, ^{o}C per 2.5 ^{o}lat) and wind (arrows, m s^{-1}) over 5^{o}-20^{o}N from (a) April 26-30 to (h) June 1-5 in sequence. Light and dark shadings denote MGT per 2.5 ^{o}lat > 0 ^{o}C and > 1 ^{o}C, respectively. The contour or ± 0.1^{o}C per 2.5 ^{o}lat is shown in particular.

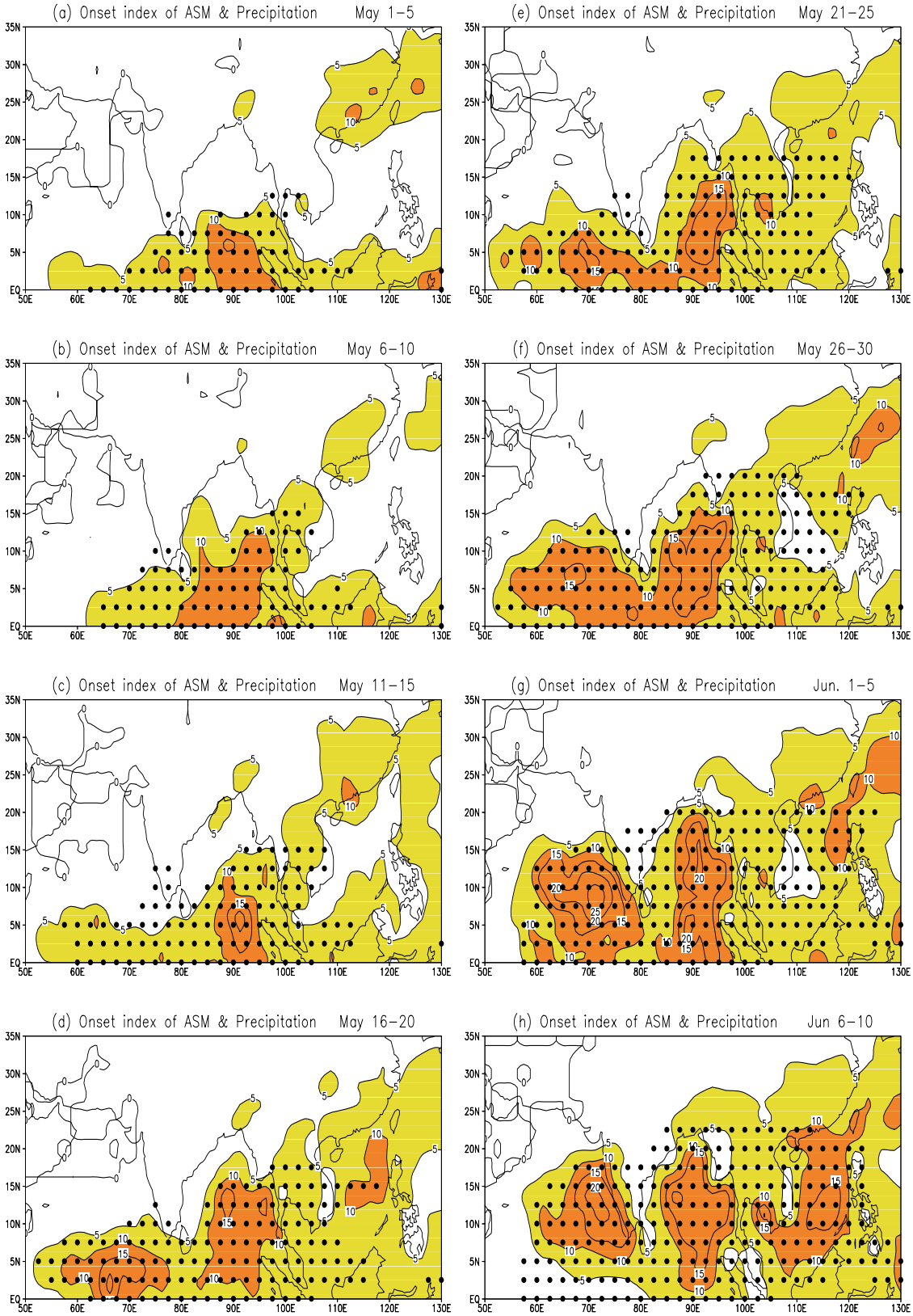

Fig. 2. Climatological advance of the Asian summer monsoon onset denoted by closed circles and precipitation rate (mm day^{-1}) from May 1-5 (a) to June 6-10 (h) in sequence. Contour interval for precipitation rate is 5 mm day^{-1}, with light and dark shading indicating the values > 5 mm day^{-1}and > 10 mm day^{-1}, respectively. Data used here is the Climate Prediction Center Merged Precipitation(CMAP).